A Global Identification Method for Linear Parameter-Varying (LPV) Systems

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The identification of linear parameter-varying (LPV) systems remains a challenging problem, even though it has received a lot of attention in recent years. In the literature, two different approaches can typically be distinguished: local and global. The local identification techniques assume that linear time-invariant (LTI) models of the system can be identified for different fixed values of the scheduling parameter(s). In a second step, these LTI models are interpolated to obtain a parameter dependent model. The global techniques directly identify a parameter dependent model based on data obtained from one experiment where the system is excited while the scheduling parameters are constantly changing. In this contribution a LPV identification method is presented which combines both approaches: a local technique [1] that provides an initial guess for a global approach inspired by the Polynomial Nonlinear State Space (PNLSS) identification method [2].

1 Methodology

The PNLSS model is a time-invariant state space model that consists of a linear part and a nonlinear part that consists of monomials in the states and inputs up to a desired degree. With the proper modifications, the concept of PNLSS identification can be adopted to identify LPV systems. The scheduling parameters are considered as additional inputs and rearranged into chosen basis functions. A basis that is not restricted to monomials, is selected for the scheduling parameters. The nonlinear elements of the LPV model are a product of the real system inputs and states with these basis functions of the scheduling parameters. The model parameters are the coefficients of these nonlinear elements and the elements of the linear part of the model. Measurements used for the parameter estimation are taken from a global identification experiment. What follows is a nonlinear least squares optimization problem, which can be solved by the Levenberg-Marquardt algorithm, with a good initial guess provided by the SMILE technique [1].

2 Simulation results

The proposed identification procedure is applied to a mass-spring-damper system with varying stiffness. The system input is the force applied to the mass ($m = 0.5$kg), the output is the position of the mass. The input-output data are obtained by applying a multisine input force excitation while varying the stiffness sinusoidally at a frequency of 0.13 Hz within the range $k \in [3,7]\,\mathrm{kg/s^2}$. The obtained LPV model is validated for a broad range of validation data sets and compared with the SMILE model [1]. This comparison revealed that the new LPV identification method outperforms the SMILE technique. Figure 2.1 shows the results for one of these validation data sets, where the stiffness is varying within the range $k \in [1,9]\,\mathrm{kg/s^2}$ at the frequency of 0.22 Hz.

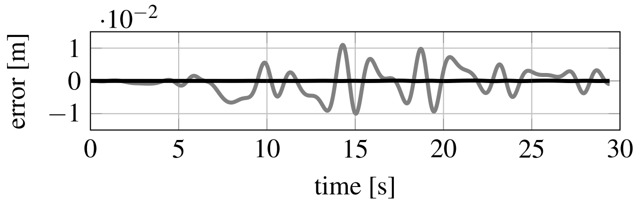

Figure 2.1: Simulated output error obtained with the SMILE (grey; MSE $= 1.5318^{-5}$) and the new (black; MSE $= 9.6736^{-10}$) technique. MSE = mean square error.

3 Conclusion and upcoming concept

In the future research, this approach will be further tested on more complex systems that demand more extended bases of the scheduling parameters, including dynamic scheduling parameter dependency. Next, minimization of the number of nonlinear model elements via ℓ_1-norm regularization and automatic selection of the scheduling parameter basis will be investigated.

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